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DEPOT SUPPORT OF GAS TURBINE ENGINES.(U)
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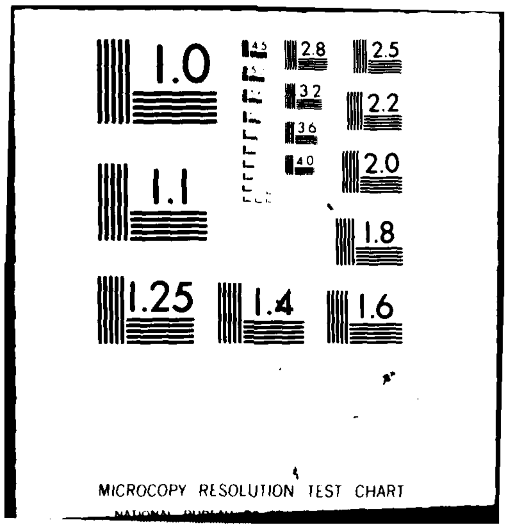
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DEPOT SUPPORT

OF

GAS TURBINE ENGINES

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David V. Glass

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This report assesses the DoD's capacity and capability to support the depot maintenance requirements of gas turbine engines over the next 5-10 years. Special attention is given to newer nonaeronautical applications (tanks, marine propulsion, and cruise missile).

Gas turbine engines used in fixed and rotary wing aircraft will continue to dominate the engine workload; the gas turbines used in cruise missiles, tanks, and ships will comprise less than 10 percent of the total engine workload by 1990.

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20. ABSTRACT (Cont'd)

Additional depot maintenance capacity to support gas turbine engines is not required. The depots have adequate capacity today, and since the gas turbine workload is projected to increase by only 6 percent between FY 82 and FY 87, capacity should remain adequate through the 1980s.

The Military Departments have the required capabilities to support the new nonaeronautical gas turbine engines entering the DoD inventory. They have repaired similar engines, both in size and technology, for several years.

EXECUTIVE SUMMARY

The question at hand is whether the Department of Defense has the required organic depot capacity and capability to support its gas turbine engine population during the 1980s. The answer is YES--depot maintenance of gas turbines should not present any untoward problems to DoD during the period.

The DoD's traditional use of gas turbine engines as propulsion units for fixed and rotary wing aircraft recently has been extended to a variety of new applications, primarily the cruise missile, the M1 tank, and the DD-963 and FFG-7 class ships. While only a few hundred engines for these new applications are in the inventory, several thousand are planned to be procured during the 1980s.

The Military Departments forecast turbine engine program workload, in direct labor hours, to increase about 6 percent (from 6.3 to 6.7 million) during the period FY 82 through FY 87. The DoD's aggregate peacetime capacity to support gas turbines is more than adequate today; the modest increase in workload through the 1980s should not exert any significant pressure on existing capacity.

About 40 percent of the increased workload will be on aircraft (fixed and rotary wing) turbines which in 1987 will continue to generate 85 to 90 percent of the total workload. Increasing workload associated with new aircraft engines will be largely offset by declining workload on maturing engines and those being phased out. The gas turbines used on combatant ships, tracked vehicles, and cruise missiles account for 60 percent of the forecasted increase in workload but will comprise only about 5 percent of the total

workload by FY 87. The balance of the workload will be on miscellaneous small engines, a program forecast to remain stable during the 1980s.

Depot capability to support gas turbines also should not be a problem through the 1980s. The gas turbines in use or planned for new applications are similar in size and technology to those currently being reworked in DoD depots. The skills and techniques used to rework turbines are not markedly disparate among engines. While there is variation in special tools and test equipment, these are not major items.

The relatively stable mix and size of forecasted workload, existing depot capacity, and similarity of the gas turbines to be reworked, taken together, indicate that depot rework of gas turbines should not require other than routine OSD attention during the 1980s.

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1. INTRODUCTION

The gas turbine engine has long been the principal powerplant for military aircraft. Uses for such engines have recently expanded into a variety of new systems: the Army's M1 tank is powered by the Lycoming AGT1500; the Navy uses General Electric's LM2500 in several classes of ships, including the DD-963 and FFG-7; the Williams Research F107 powers various cruise missiles. Gas turbine engines are also used in mobile electric power generators.

This study was undertaken to determine whether the DoD has adequate gas turbine engine depot maintenance capacity and capability through the 1980s, particularly with regard to the projected workload arising from the new gas turbine applications. Specifically, the following questions were to be answered:

- Is the capacity of the depots which perform depot maintenance on gas turbines at least as large as the projected workload?
- Will new gas turbine technology require the development of new or enhanced depot maintenance capabilities?

We concentrated on the DoD organic facilities vis-a-vis projected peacetime workload. Although the issues involve the total gas turbine workload, we placed special emphasis on problems unique to or stemming from the new applications. The projections of gas turbine engine depot maintenance workloads were obtained from the Military Departments and appropriate joint service organizations. The Air Force Logistics Command, Naval Air Logistics Center, and the Army Depot System Command supplied much of the workload data. Figures for the F107 were provided by the Joint Cruise Missile Project Office. Capacity figures were supplied by the Military Departments and the Joint Aeronautical Depot Maintenance Action Group (JADMAG).

In addition, we visited several depot maintenance facilities. Discussions with depot personnel were invaluable in providing background on the nonquantifiable issues concerning capability, capacity, and workload data, especially since problems with the data structure made a direct comparison of workload with capacity somewhat difficult.

The data and supporting information are contained in three appendices. Appendix A identifies the engines considered, their manufacturer, and the depot(s) providing support. Appendix B contains the workloads projected for each engine for FY 82-87, and the breakdown of the total workload by depot for each of those years. Appendix C contains the engine production shop capacity of each depot.

2. GENERAL INFORMATION

THE TECHNOLOGY

The gas turbine engine is characterized by its high power to weight ratio and its inherently reliable design. In general, all gas turbine engines have three parts: a compressor which increases the density of the air, a combustor which mixes the compressed air with fuel and then burns it creating kinetic energy, and a turbine which translates the kinetic energy into mechanical energy.

There are four basic classes of gas turbine engines: turbojet, turbofan, turboshaft, and turboprop. These differ in the amount of kinetic energy that is used to power the turbine and how the resulting mechanical energy is used. In a turbojet, the turbine powers only the compressor, and the output of the engine is the thrust resulting from the hot gases of combustion. In the turbofan, a fan, powered by a second turbine behind the compressor turbine, is placed in front of the compressor to augment the thrust. In turboshaft and turboprop engines, the turbine powers both the compressor and a shaft or propellor. Within the four classes, the engines vary in power, application, size, and weight. For instance, the weight can vary from the 7,200 pound TF39 turbofan used in the C-5A to the 75 pound T62 turboshaft used as an auxiliary power unit in the CH-53.

The efficiency of all gas turbine engines is driven by increasing pressure ratios and achieving higher turbine inlet temperatures. Enhancements are achieved by closer tolerances in the rotating parts and extensive use of exotic metals in the hot sections of the engine, regardless of engine size. In general, engine technology varies as much with the date of design as with

the application. Nonetheless, engine development is an evolutionary process--similarities between engines are far greater than differences.

This common technology allows us to speak of the overhaul and repair of gas turbine engines generically. Obviously some engines, because of their large size, require special handling and large work areas. All require some special tools and test equipment. Overall, however, the skills and techniques used to repair gas turbine engines do not differ significantly.

THE REPAIR PROCESS

The same basic repair process is followed for all gas turbine engines. Because most engines are on some form of On Condition Maintenance, or Reliability Centered Maintenance, many no longer receive a complete overhaul. The repair process begins with a review of the engine's records, so work orders can be prepared for that particular engine. This is followed by inspecting, in some cases even testing, the engine prior to or at disassembly. The engine is disassembled to the level required to accomplish the repair. The parts and components which require repair, due either to malfunction or because they are reaching the end of their useful life, are then cleaned and inspected. The inspection typically includes nondestructive testing using penetrants or eddy currents. Defective parts are then routed to production shops for repair, or are condemned. Some parts, such as turbine blades, become worn below tolerances and require rebuilding. This is usually a two-part process involving some sort of buildup, electroplating or metal spray for example, and then machining to return the part to specifications. Compressor cases might require welding or machining. Eventually the parts are brought together for assembly. First the rotating assemblies, i.e., the compressor section and the turbine section, are assembled and balanced. They are then joined with th combusto and finally, the whole engine is built up and the

accessories, such as fuel controls, are attached. The engine is then taken to a test cell for final test and calibration.

The repair process described has been for a complete engine. Several of the more advanced engines, however, are not designed to be returned to the depot as complete engines. They are modular, and only the individual modules are returned. The same basic flow of inspection, disassembly, repair, and assembly is also followed with the modules.

Engine components also are repaired at the depots and generate a large workload of their own. Component workload is generally documented separately from the engine program workload. The engine program workload can be thought of as work done to the engine and to those components which are reworked concurrently with the engine. If a component is removed from an engine and replaced with a spare from the supply system, then the work done to the removed component will be charged to the component program, *not* to the engine program.

THE FACILITIES

Eight major depot maintenance facilities in the DoD perform maintenance of gas turbine engines. The Air Force facilities are the Air Logistics Centers (ALCs) at Oklahoma City and San Antonio. The Navy has five Naval Air Rework Facilities (NARFs): Alameda, Cherry Point, Jacksonville, Norfolk, and North Island (San Diego). The Army has a major facility at Corpus Christi and a facility at Tooele, Utah, with a very small workload. In addition, the Army is planning to perform somewhat less than depot-level maintenance on the AGT1500 engine at Anniston and Mainz (Federal Republic of Germany).

Complete rework of gas turbine engines, modules, and components requires sophisticated processes and equipment. To meet the close tolerances required, numerical control machinery, precision lathes, balancing equipment and other

capabilities are needed. To deal with the exotic materials, electron beam welding and vacuum heat treat equipment are required. Also needed are test cells, properly configured for the given type of engine, and other general equipment. All the major facilities have these capabilities as well as other specialized tooling and processes specific to their particular mission.

Because of the commonality of the equipment needed for gas turbine engine rework (and hence, the skills), any major facility can repair an engine of the same general size and characteristics as those it presently repairs. Corpus Christi, which primarily supports helicopter engines, has the capability to maintain any new helicopter engine or other small engine. Naturally, new tools, technical publications, and perhaps some new machinery would be required, but no major investment would be necessary. However, Corpus Christi would require extensive changes to support a large turbofan engine such as the TF-39 because of the space and special handling equipment required, and the test cells needed to accommodate the thrust it develops.

3. GAS TURBINE WORKLOAD

Table 3-1 shows the projected gas turbine engine workload, by major application, for the FY 82-87 period. The aircraft workload is separately identified by rotary and fixed wing application. The small engines include start carts, and auxiliary and mobile electric power units. In the balance of this chapter, we discuss and evaluate the workloads shown in Table 3-1, beginning with the new gas turbine applications.

TABLE 3-1. GAS TURBINE WORKLOAD BY APPLICATION

Application	FY 82		FY 83		FY 84		FY 85		FY 86		FY 87	
	Hours[1]	Percent[2]	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent
Aircraft	5,537	88	5,976	88	5,824	87	5,537	86	5,658	85	5,708	85
Rotary Wing	(838)	13	(838)	12	(856)	13	(819)	13	(844)	13	(912)	14
Fixed Wing	(4,699)	75	(5,138)	76	(4,968)	75	(4,718)	73	(4,814)	73	(4,796)	71
Small Engines	680	11	679	10	684	10	695	11	684	10	695	10
Tank	21	0	34	1	63	1	94	1	127	2	165	2
Marine	67	1	70	1	79	1	79	1	84	1	•84	1
Cruise Missile	0	0	3	0	13	0	61	1	74	1	86	1
TOTAL[3]	6,305	--	6,762	--	6,663	--	6,466	--	6,627	--	6,728	--

[1]Hours are in thousands of direct labor hours.

[2]Percent of total FY workload.

[3]Columns may not total due to rounding.

NEW APPLICATIONS

Cruise Missile

The air, sea, and ground launched cruise missiles will enter the DoD inventory early in the 1980s, building to a total of 4,700 missiles by 1990. These missiles will be powered by the Williams Research F107 turbofan engine. While there are some differences in the location of accessories among the applications, the engines are essentially identical. The F107 is a small (141 pounds) twin spool turbofan, and is derived from a Williams Research turbojet

of which over 4,000 have been produced. According to the Joint Cruise Missile Project Office, which manages all three missiles, the depot maintenance support for the F107 will be provided solely by the manufacturer until at least September 1987. Thereafter, dual support may be provided by Williams Research and either Teledyne or Oklahoma City ALC. This decision should be made in FY 83.

In FY 87, the projected depot maintenance workload for the F107 is between 61,000 and 120,000 direct labor hours, with a best estimate of 86,000 hours. The wide range results from the many uncertainties about the maintenance requirements of the engine. Unlike most engines, these will not be run in the field on a routine basis. Consequently, there can be no indication of failure without periodic testing. Current plans call for the engine to be returned to the depot every 30 months for recertification, but this interval could be substantially adjusted based upon depot experience. As the force matures, better factors will be derived using sampling and lead-the-force techniques. Given the assumptions of recertification every 30 months, with 50 percent of the recertifications being major and 50 percent minor, the depot workload should reach a plateau of 175,000 direct labor hours annually in the early 1990s.

Marine Propulsion

Beginning with the introduction of the DD-963 class in 1975, gas turbine engines have powered most of the Navy's new combatants, including the FFG-7, DDG-993, CG-47, and PHM-1 class ships. All of these classes use the General Electric LM2500 gas turbine engine, a derivative of the TF39 engine used on the C-5A. (The program manager for the LM2500 engine is the Marine Gas Turbine Project Office.) Because it is used in a marine environment, the LM2500 has been made more corrosion resistant, primarily through the use of coatings, and retains only 30 percent commonality with the TF39.

The depot support for the LM2500 is provided by NARF, North Island, which will continue to be the sole source for depot maintenance. The FY 82 workload is predicted to be approximately 23,000 direct labor hours, increasing to 41,000 hours by FY 87. The workload could increase to approximately 55,000 hours by the early 1990s if the Navy shipbuilding plan is followed. Some additional depot-level maintenance is performed aboard ship by depot teams; this workload is not included in any of the projections. Since the LM2500 has been in use since 1975, the major uncertainties in the workload projections are probably related to the shipbuilding schedule rather than to the engine.

The Allison 501K17 provides electric power on the DD-963, DDG-993, and CG-47 class ships. It also is managed by the Marine Gas Turbine Project Office and is maintained at NARF, Alameda. The projected FY 82-87 workload averages approximately 43,000 hours per year.

Together, the LM2500 and 501K17 depot maintenance program is expected to increase from 67,000 direct labor hours in FY 82 to 84,000 hours in FY 87, approximately one percent of the total DoD depot workload.

The Navy may build a class of gas turbine engine powered air-cushion landing craft (LCAC). The engine for the LCAC has not been selected. In addition, the LM2500 may be chosen as the powerplant for the DDGX. The effect of either program on the gas turbine engine depot maintenance workload in the next 10 years should be negligible.

Tank Propulsion

The use of the AVCO-Lycoming AGT1500 gas turbine engine in the M1 tank is the first DoD use of a gas turbine in a ground combat vehicle. This application is a challenging environment for a gas turbine engine. The Army plans depot maintenance of the AGT1500 at three Army depots. Anniston and

Mainz will perform the primary maintenance function with support from Corpus Christi and contractors. Since Anniston and Mainz have not previously maintained gas turbines, depot repair will be accomplished through a remove and replace procedure, with unserviceable components returned to Corpus Christi for repair. Consequently, spares must be stocked at both Anniston and Mainz and a spares pipeline established between these depots and Corpus Christi (and possibly some contractors). Until Anniston and Mainz personnel acquire familiarity with the engine, inexperience will inflate the requirement for spares, as traditionally occurs with new engines. To complicate the situation, Corpus Christi has recently had problems with the quality and quantity of spares which Lycoming is supplying for the T53 and T56 helicopter engines. Should Lycoming have similar problems with AGT1500 spare parts, serious trouble for the AGT1500 maintenance program would occur.

According to current production schedules, the M1 population will increase from 1,200 in FY 82 to 6,300 in FY 87 to over 7,000 in the 1990s. The resulting depot maintenance workload for the AGT1500 engine is projected to increase from 21,000 direct labor hours in FY 82 to 165,000 in FY 87. These projections include only the Anniston and Mainz engine programs.

Mobile Electric Power

The use of gas turbine engines to provide mobile electric power is not a new application. However, it appeared at one time that their use would expand beyond the traditional start carts, auxiliary power units (APUs), and a few specialized Army applications to encompass all mobile electric power generation in the DoD. This is no longer the case because of increased fuel costs. In fact, diesels are now being considered as power sources for aircraft APUs and start carts, traditional gas turbine applications.

The Army identified only one gas turbine powered mobile electric power generator (MUST). Its projected workload is extremely small. MUST is being maintained at Tooele, which will also support generators used in the Patriot missile system. That workload is also expected to be small.

TRADITIONAL APPLICATIONS

Aircraft

The major use of gas turbine engines in the DoD is, and will continue to be, for aircraft propulsion. The range of sizes and characteristics of such engines reflects the range of aircraft in the inventory. The projected FY 87 depot maintenance workload for these engines will be approximately 5.7 million direct labor hours, or 85 percent of the total DoD gas turbine engine program. Almost 912,000 of these hours will be in support of helicopter engines, the balance will be for engines powering fixed wing aircraft.

The projected workload includes several new engines entering the inventory, such as General Electric's F404 and T700 engines. The F101 engine is not included, although a resurrection of the B-1 bomber program or equivalent could result in some F101 workload by the end of the decade.

Small Gas Turbines

The other traditional applications of gas turbine engines are airborne APUs and ground support equipment, such as start carts for aircraft. Both of these applications use gas turbine engines that are generally smaller and of somewhat simpler design than aircraft engines.

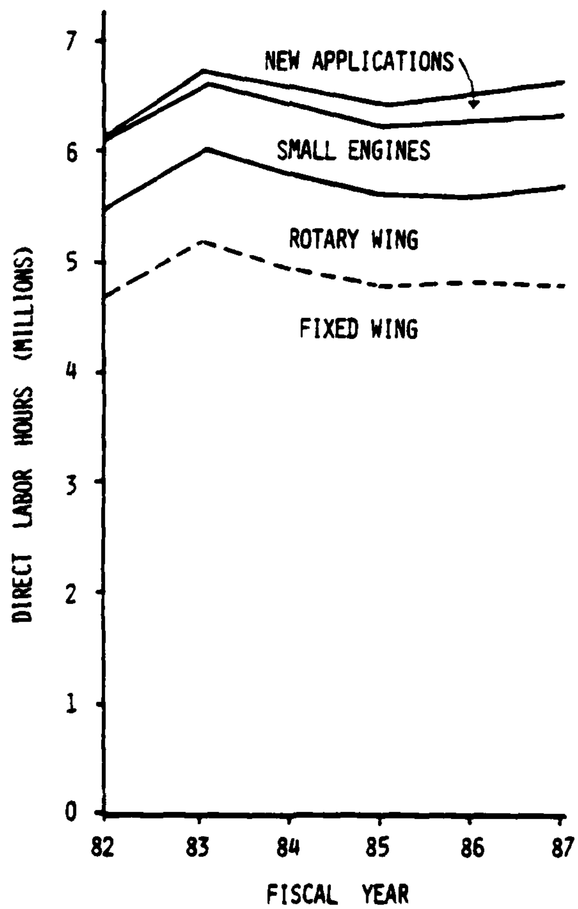
The projected depot maintenance workload for all types of start carts and APUs is close to 700,000 direct labor hours annually through 1987. Over 490,000 direct labor hours will be required to support four engines at

San Antonio ALC. The Navy will repair small engines at NARF, Alameda and NARF, Cherry Point (totaling approximately 190,000 hours annually).

ANALYSIS OF PROJECTED WORKLOADS

The total depot maintenance workload for gas turbine engines is projected to increase from 6.3 million direct labor hours (DLHs) in FY 82 to 6.7 million hours in FY 87, a growth of 6 percent over 5 years. The increase will be split between the traditional aircraft and small engine applications (176,000 hours) and the new applications (247,000 hours). Figure 3-1 shows the gas turbine program by application and fiscal year. With the exception of the

FIGURE 3-1. ENGINE PROGRAM WORKLOAD BY FISCAL YEAR



hump in FY 83--largely due to the planned conversion of the TF30-P414 to TF30-P414A at NARF, Norfolk--the graph shows small, steady growth over the 5-year period.

In FY 82, aircraft engine workload will constitute 88 percent of the total DoD gas turbine workload, dropping slightly to 85 percent in FY 87. Figure 3-2 clearly shows this dominance of the aircraft workload. Even considering the uncertainty in the projected workload, the new gas turbine applications will account for only a relatively small amount of depot workload by FY 87. With the great disparity in workload between the traditional and new applications, even a 100 percent error in projecting the workload for the new segment would hardly change the proportions.

FIGURE 3-2. GAS TURBINE ENGINE DEPOT WORKLOAD BY TYPE

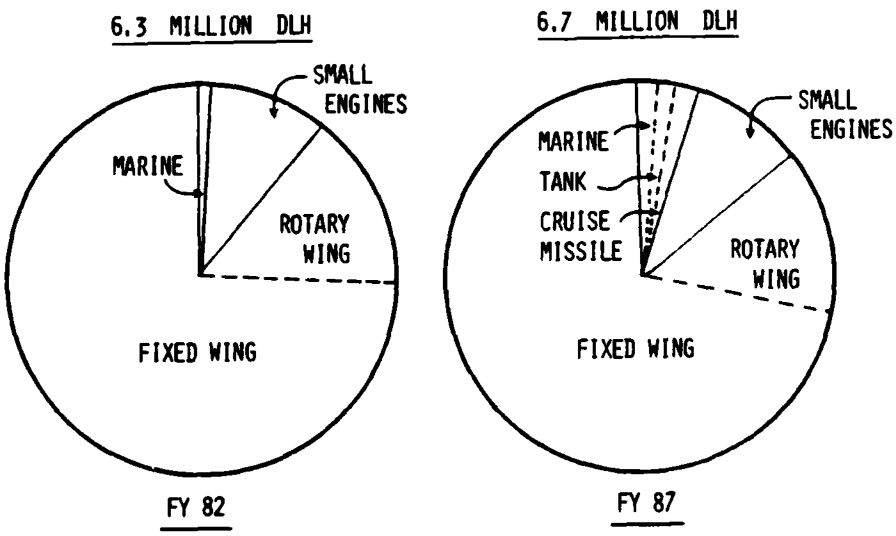


Table 3-2 shows the workload projections broken out by the Military Department performing the maintenance. Between FY 82 and FY 87, the Air Force program is expected to grow by 14 percent, the Army's program by 48 percent, while the Navy's program will decline by 17 percent. The primary cause of the Air Force growth is the F100. That engine's workload is expected to increase

by almost 400,000 direct labor hours between FY 82 and FY 87. In the Army, the AGT1500 and T700 workloads are projected to increase by a total of 312,000 hours. The Navy decline is led by the J79 (132,000 hours), the F402 (120,000 hours), and the J52 (94,000 hours).

TABLE 3-2. PROJECTED GAS TURBINE ENGINE WORKLOAD

Military Department	Direct Labor Hours (000s)					
	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87
Air Force[1]	3,496	3,586	3,741	3,803	3,962	4,002
Army	598	660	718	736	783	887
Navy	2,211	2,516	2,204	1,927	1,882	1,839
TOTAL	6,305	6,762	6,663	6,466	6,627	6,728

[1] Includes cruise missile workload

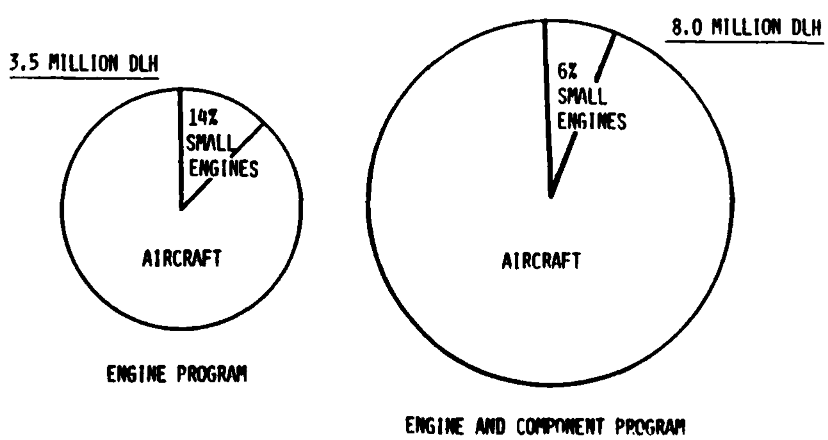
Also of note in Table 3-2 is the increasing Air Force share of the total DoD gas turbine workload, from 55 percent in FY 82 to 59 percent in FY 87. Some of this growth is due to the cruise missile (86,000 hours in FY 87). However, as mentioned earlier, it is possible that this workload may all be performed on contract.

Workload projections to the end of the 1980's were not available for most engines, but there are no indications of a substantial change from that already presented. The F107 workload is expected to double by 1991 (but some, if not all, will be satisfied commercially). The marine propulsion workload will also double if the Navy shipbuilding schedule proceeds as planned. The M1 tank procurement schedule calls for over 6,300 tanks to be procured by 1987, out of a total 7,058 planned procurement. Consequently, additional growth in the depot program for the AGT1500 engine can be expected if the depot maintenance requirements for the engine lag the production schedule of

the tank. However, one would expect that the difficulties likely to be encountered in the early stages of the AGT1500 program will have been surmounted by then. Thus, it is clear that the traditional gas turbine applications will provide the bulk of the workload at the end of the 1980's, with the new applications not more than 10 percent of the total.

The gas turbine engine projections discussed above include only the engine program, not the workload generated by engine accessories and components flowing through the supply system. Consolidating the component and engine workload accentuates the predominance of the aircraft segment. Figure 3-3 shows the Air Force's FY 82 workload for both the engine program and the combined engine and component program. Generally, the larger the engine, the more component work. The ratio of component workload to engine program workload is almost six to one for the TF-39, one to one for the J-79, one to four for the T-56. These engines weigh 7,200, 3,700, and 1,800 pounds, respectively. Since the new applications, with the exception of the LM2500, are small engines, the inclusion of components and accessories for all engines leads to workload projections dominated even more by the traditional applications.

FIGURE 3-3. AIR FORCE FY 82 GAS TURBINE ENGINE DEPOT WORKLOAD



4. CAPACITY

DEFINING DEPOT CAPACITY

DoD 4151.15H, "Depot Maintenance Production Shop Capacity Measurement Handbook," prescribes two capacity measures--physical and peacetime. Physical capacity is defined as the amount of workload, expressed in direct labor hours, that a facility can generate with all work positions manned on a single-shift, 5-day, 40-hour week basis while producing the product mix that the facility was designed to accommodate. Peacetime (workloading) capacity is defined as the amount of workload, expressed in direct labor hours, that a facility can effectively apply considering the management limitations upon applying sufficient workers to continuously fill every work position on a single-shift, 5-day, 40-hour week basis while producing the product mix that the facility was designed to accommodate. A depot's capacity, either physical or peacetime, is essentially one measure of the size of a facility.

As defined, depot maintenance capacity is measured as the number of direct labor hours which can be applied. Consequently, it is a surrogate for production potential. Workload standards (in labor hours) for the same job vary from depot to depot, so different capacities can produce equal output. The use of labor hours to measure capacity sometimes leads to nonintuitive results, as recently occurred at NARF, Alameda. A renegotiation of a labor contract reduced the number of operators for each engine test cell from two to one. This halved the capacity of each test cell, as measured in labor hours, but had no effect on production.[1] The same number of engines are being processed through the cells.

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[1]The second operator's main function was safety, especially when an operator was required to enter the cell with an engine running. The new procedure is to use an operator from another cell when this is necessary.

The structure of the data also creates difficulty in defining a reasonable "gas turbine engine capacity." The capacity data supplied by the Military Departments and the JADMAG are organized by production shops--airframe, engine, accessories and components, test and calibration, etc.--as specified in DoD 4151.15H. But not all engine work is accomplished in the engine shop. Much work on engine components is done in the components shop, which does not exclusively support engines. Many other accessories and components also are repaired in the components shop. Consequently, the Military Departments have difficulty in quantifying the extent of their components shop capacity which is engine related.

As a result, the broadest definition of engine workload--engine program plus engine components program--cannot be directly compared with just the engine production shop capacity. It also is inappropriate to compare this workload with the capacity of the engine shop and the accessories and components shop together, as not all of that capacity is dedicated to engines. We can, however, consider engine shop workload alone and compare that to engine shop capacity.

WORKLOAD VERSUS CAPACITY

Table 4-1 shows engine production shop capacity, physical and peacetime, and projected FY 83 engine program and engine shop workloads by Military Department.[2] Also shown in Table 4-1 is each Department's projected utilization of peacetime capacity. Each Department estimates peacetime capacity to be approximately 80 percent of physical capacity. The projected shop workloads differ substantially from that of the engine programs, however. The Air Force forecasts an engine shop workload 37 percent greater than its engine

[2]FY 83 was selected because engine shop workload is projected to peak in that year; more detailed data on engine shop capacity are provided in Appendix C.

program, while the Army and Navy anticipate their shop workloads to be 54 and 15 percent less than their engine programs, respectively. Different maintenance philosophies certainly contribute to these differences, along with the specific engines being supported. Both the Army and the Navy have a comfortable margin in engine shop capacity, with engine shop utilization rates below 80 percent. The Air Force apparently has little excess capacity. In aggregate, DoD's peacetime engine shop capacity should be adequate to satisfy the FY 83 workload.

TABLE 4-1. FY 83 ENGINE SHOP CAPACITY AND UTILIZATION BY MILITARY DEPARTMENT

Military Department	Physical Capacity	Peacetime Capacity	Engine Program Workload	Engine Shop Workload	Percent Peacetime Utilization
Air Force	6,242	4,946	3,586	4,908	99
Army	525	424	660	305	72
Navy	3,526	2,795	2,516	2,133	76
TOTAL	10,293	8,165	6,726	7,346	90

Capacity and workload in thousands of direct labor hours.

Table 4-2 displays the engine shop capacities and workloads, and peacetime utilization for individual depots in FY 83. All but three depots--San Antonio, Corpus Christi, and Cherry Point--have a good margin of engine shop capacity. The 112 percent utilization of the San Antonio engine shop reflects primarily the increasing F100 engine workload. However, the Air Force plans to move the J79 program from San Antonio to Oklahoma City, thereby alleviating some of the pressure on the San Antonio engine shop. The 103 percent utilization at Cherry Point is not a long-term problem. Cherry Point's engine shop utilization is decreasing; it is projected to be approximately 80 percent in FY 87. Corpus Christi's engine shop utilization is misleading.

TABLE 4-2. FY 83 ENGINE SHOP CAPACITY AND UTILIZATION BY DEPOT

Depot	Peacetime Capacity	Engine Program Workload	Engine Shop Workload	Percent Peacetime Utilization
Oklahoma City	2,088	1,170	1,693	81
San Antonio	2,858	2,416	3,215	112
Anniston/Mainz	78	34	16	21
Corpus Christi	291	624	287	99
Tooele	55	2	2	4
Alameda	604	478	527	87
Cherry Point	388	468	401	103
Jacksonville	473	369	250	53
North Island	585	367	357	61
Norfolk	745	834	598	80

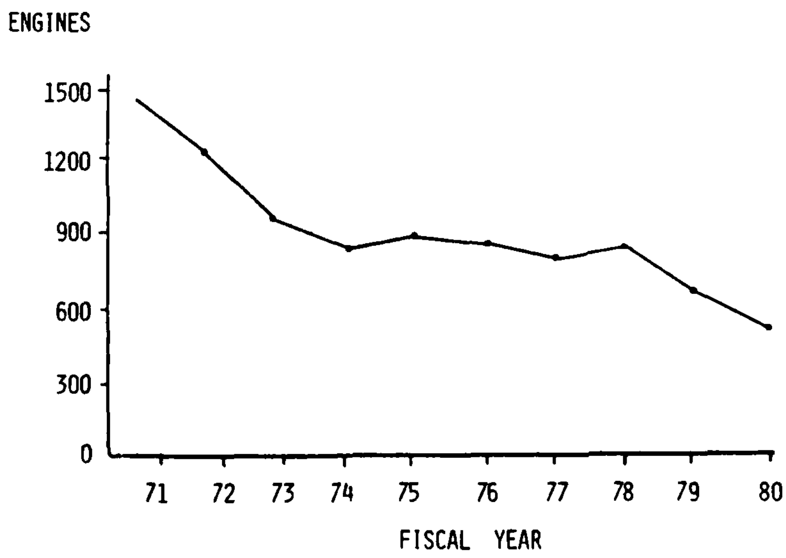
Discussions with engine production personnel at Corpus Christi led us to believe that the engine shop there is presently underutilized and programmed to remain underutilized for several years. A desire for additional work was mentioned more than once--hardly consistent with the planned 99 percent utilization rate. The discrepancy may lie in the Army's engine shop capacity figure of 291,000 hours. The JADMAG estimates the Corpus Christi engine shop capacity to be 457,000 hours, 57 percent greater than the Army's estimate. (The difference is no doubt due to different definitions of what comprises the engine shop.) Using the JADMAG figure, we obtain a utilization rate of 63 percent for the Corpus Christi engine shop, which is more consistent with the existing level of activity.

A HISTORICAL PERSPECTIVE

The comparison of engine shop capacities and planned engine shop workloads points to a conclusion that adequate gas turbine engine capacity exists today within the DoD. However, differences between engine shop workloads, engine program workloads, and engine program plus engine component workloads

tend to obscure the analysis. The difficulty in finding a true gas turbine engine capacity, rather than simply engine shop capacity, complicates the situation further. However, it is possible to use historical engine production data to further support the conclusion of adequate capacity. Figure 4-1 shows the number of engines overhauled or repaired at NARF, North Island during the last 10 years. The mix of engines supported by North Island has stayed approximately the same over this period. Although there are many factors preventing a direct comparison of 1971 with today, Figure 4-1 clearly shows that North Island has significant potential for more production. Nor is North Island unique. Corpus Christi typically had about 1,600 engines in its repair pipeline in the early 1970s; the average pipeline now is on the order of 300 engines. This same picture, with variations, is repeated elsewhere.

FIGURE 4-1. ENGINE PRODUCTION AT NARF, NORTH ISLAND



5. FINDINGS AND CONCLUSIONS

Four principal findings emerge from this review:

- The gas turbine engines planned for cruise missile, tank, and marine applications are similar in technology to engines already being repaired in DoD depots.

- The total gas turbine engine workload is not expected to change appreciably over the next 5 to 10 years.

- Gas turbine engines used in fixed and rotary wing aircraft will continue to dominate the engine workload; the gas turbines used in cruise missiles, tanks, and ships will comprise only 5 to 10 percent of the total engine workload by 1990.

- The DoD has adequate depot maintenance capacity to support projected gas turbine requirements of the Military Departments.

We conclude that additional depot maintenance capacity to support gas turbine engines will not be required prior to 1990. The DoD has sufficient aggregate capacity today, and since the gas turbine workload is not projected to increase substantially, capacity should remain adequate through the 1980s.

We also conclude that the Military Departments have the required capabilities to support the new nonaeronautical gas turbine engines that are entering the DoD inventory. The Departments have repaired similar engines, both in size and technology, for several years. Nevertheless, Anniston and Mainz Army Depots, with new gas turbine responsibilities, deserve special attention. Inexperience, coupled with reliance on possibly inadequate spares support, provide a potential for inordinate difficulty in supporting the AGT1500 at depot level. The ASD(MRA&L) may wish to give this program special attention during near-term POM reviews.

Anniston and Mainz are not the only depots which must be concerned with the spares problem. Lack of parts is perceived throughout the DoD depot

maintenance community as a significant cause of lost productivity. Of all impediments to depot performance, this is perhaps most crucial.

It is recognized that funding for spares and repair parts recently has received more favorable treatment during the budget process. In addition, special analyses are underway to find more economical ways to provide spares support during the introductory phases of new systems. ASD(MRA&L) assistance to the Military Departments in achieving improved spares and repair parts stockage positions will pay large dividends in increased depot productivity.

APPENDIX A

GAS TURBINE ENGINES IN THE DOD

Tables A-1, A-2, and A-3 portray the manufacturer, primary application, and repair depot for all organically maintained Air Force, Army, and Navy gas turbine engines, respectively.

TABLE A-1. AIR FORCE MAINTAINED GAS TURBINE ENGINES

Engine	Manufacturer	Primary Application	Repair Depot
F100	Pratt & Whitney	F-15,F-16	San Antonio
F107	Williams Research	Cruise Missile	Oklahoma City[1]
G56	Allison	Auxiliary, Ground Power	San Antonio
GTC85	Garrett	Auxiliary, Ground Power	San Antonio
GTCP165-1	Garrett	Auxiliary, Ground Power	San Antonio
GTCP85	Garrett	Auxiliary, Ground Power	San Antonio
J57	Pratt & Whitney	B-52G,KC-135A	Oklahoma City
J75	Pratt & Whitney	F-105F,F-106A	Oklahoma City
J79	General Electric	F-4E,RF-4C	San Antonio
T56	Allison	C-130H,HC-130H	San Antonio
T41M-9A	Solar	Auxiliary, Ground Power	San Antonio
TF30	Pratt & Whitney	F-111F,FB-111A	Oklahoma City
TF33	Pratt & Whitney	B-52H,E-3A,C-141	Oklahoma City
TF39	General Electric	C-5A	San Antonio
TF41	Allison	A-7D	Oklahoma City

[1]The final decision on depot support for the F107 gas turbine engine has not yet been made.

TABLE A-2. ARMY MAINTAINED GAS TURBINE ENGINES

Engine	Manufacturer	Primary Application	Repair Depot
AGT1500	Lycoming	M1	Anniston/Mainz
GT-MUST	Solar	Mobile Electric	Tooele
T53	Lycoming	UH-1H,AH-1	Corpus Christi
T55	Lycoming	CH-47C	Corpus Christi
T63	Allison	OH-58C	Corpus Christi
T700	General Electric	UH-60A	Corpus Christi

TABLE A-3. NAVY MAINTAINED GAS TURBINE ENGINES

Engine	Manufacturer	Primary Application	Repair Depot
501K17	Allison	Marine Auxiliary Power	Alameda
F402	Rolls-Royce	AV-8B	Cherry Point
F404	General Electric	F/A-18	Jacksonville/North Island
GTCP95-2	Garrett	Auxiliary, Ground Power	Alameda/Cherry Point
GTC100-54	Garrett	Auxiliary, Ground Power	Alameda/Cherry Point
J52	Pratt & Whitney	A-4F/M,A-6E	Alameda/Jacksonville
J57	Pratt & Whitney	F-8	Norfolk
J79	General Electric	F-4J	North Island
LM2500	General Electric	DD-963,DDG-993,FFG-7	North Island
T400	Pratt & Whitney	AH-1	Cherry Point
T56	Allison	P-3C,E-2C	Alameda/Norfolk
T58	General Electric	CH-46	Cherry Point/North Island
T62	Solar	Auxiliary, Ground Power	Alameda/Cherry Point
T64	General Electric	CH-53	North Island
T700	General Electric	SH-60B	Jacksonville
T74	Pratt & Whitney	U-21A,RU-21B	Cherry Point
T76	Garrett	OV-10	Cherry Point
TF30	Pratt & Whitney	F-14A	Alameda/Norfolk
TF34	General Electric	S-3A,A-10	Alameda/Jacksonville
TF41	Allison	A-7E	Alameda/Jacksonville

APPENDIX B

PROJECTED WORKLOADS FOR ALL DOD GAS TURBINE ENGINES

Tables B-1, B-2, and B-3 portray the projected engine program workload for Air Force, Army, and Navy maintained engines, respectively, for the period FY 82-87. Table B-4 shows the projected engine program workload by facility for the period FY 82-87, while Table B-5 shows the planned engine shop workload by facility for the same time period.

TABLE B-1. AIR FORCE GAS TURBINE WORKLOAD

Engine	Depot	Workload in Thousands of Hours					
		FY 82	FY 83	FY 84	FY 85	FY 86	FY 87
F100	SA	1,008	1,065	1,119	1,232	1,327	1,393
F107	OC	0	3	13	61	74	86
G56	SA	4	4	4	4	4	4
GTC85	SA	163	163	162	163	163	163
GTCP165-1	SA	6	12	6	14	10	10
GTCP85	SA	288	279	293	294	288	287
J57	OC	212	242	242	230	230	230
J75	OC	35	43	46	38	35	35
J79	SA	584	655	684	652	649	608
T56	SA	116	112	123	126	115	115
T41M-9A	SA	31	31	31	31	31	31
TF30	OC	572	514	621	610	618	621
TF33	OC	140	117	142	148	133	134
TF39	SA	120	95	72	55	87	87
TF41	OC	217	251	183	145	198	198
	TOTAL	3,496	3,586	3,741	3,803	3,962	4,002

SA = San Antonio ALC
OC = Oklahoma City ALC

Air Force (AFLC/MAJ) supplied data through FY 85. Workload hours per flying hour for the period FY 82-85 were used to derive projections for FY 86-87.

TABLE B-2. ARMY GAS TURBINE WORKLOAD

Engine	Depot	Workload in Thousands of Hours					
		FY 82	FY 83	FY 84	FY 85	FY 86	FY 87
AGT1500	AN,MZ	21	34	63	94	127	165
GT-MUST	TE	0	2	0	1	0	2
T53	CC	302	332	349	316	316	316
T55	CC	143	124	112	117	111	121
T63	CC	132	103	117	115	115	115
T700	CC	0	57	68	83	100	152
T700-MOD	CC	0	8	9	10	14	16
	TOTAL	598	660	718	736	783	887

AN = Anniston Army Depot
MZ = Mainz Army Depot
TE = Tooele Army Depot
CC = Corpus Christi Army Depot

Data provided by Army Depot System Command.

TABLE B-3. NAVY GAS TURBINE WORKLOAD

Engine	Depot	Workload in Thousands of Hours FY 82	FY 83	FY 84	FY 85	FY 86	FY 87
501K17	AL	44	42	43	41	43	43
F402	CP	144	98	86	73	47	24
F404	JX	0	0	0	7	10	16
F404	NI	0	4	19	20	30	39
GTCP95-2	AL	29	29	29	29	29	29
GTCP95-2	CP	36	36	36	36	36	36
GTC100-54	AL	39	39	39	39	39	39
GTC100-54	CP	46	46	46	46	46	46
J52	AL	47	46	62	43	40	40
J52	JX	265	259	205	185	184	178
J57	NV	43	133	115	96	96	73
J79	CP	73	117	91	59	52	44
J79	NI	164	159	132	85	75	61
LM2500	NI	23	28	36	38	41	41
T400	CP	40	38	35	31	30	32
T56	AL	220	166	129	128	125	122
T56	NV	87	138	131	120	125	123
T58	CP	86	76	74	68	69	66
T58	NI	99	82	69	67	71	68
T62	AL	19	19	19	19	19	19
T62	CP	19	19	19	19	19	29
T64	NI	113	95	99	87	90	96
T700	JX	0	0	1	2	5	7
T74	CP	11	16	16	16	16	16
T76	CP	33	23	23	23	23	23
TF30	AL	12	8	8	8	8	8
TF30	NV	311	562	411	314	289	307
TF34	AL	62	78	79	81	82	81
TF34	JX	16	15	15	15	15	14
TF41	AL	58	51	47	46	45	41
TF41	JX	72	94	90	86	83	78
	TOTAL	2,211	2,516	2,204	1,927	1,882	1,839

AL = NARF, Alameda
CP = NARF, Cherry Point
NI = NARF, North Island
NV = NARF, Norfolk
JX = NARF, Jacksonville

Workload for FY 82 estimated from induction schedule; workload for APUs (T62, GTCP95-2, GTC100-54) estimated from induction schedule supplied by NALC 223; other workload supplied by NALC Long-Range Planning (NALC 203). The Marine Gas Turbine Project Office identified a very small amount of LM1500 workload, but NALC 203 did not include the LM1500 in its program.

TABLE B-4. GAS TURBINE ENGINE PROGRAM WORKLOAD BY DEPOT

Depot	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87
Air Force						
Oklahoma City	1,176	1,170	1,247	1,232	1,288	1,304
San Antonio	2,320	2,416	2,494	2,571	2,674	2,698
Army						
Corpus Christi	577	624	655	641	656	720
Anniston/Mainz	21	34	63	94	127	165
Tooele	0	2	0	1	0	2
Navy						
Alameda	530	478	455	434	430	422
Cherry Point	487	468	426	370	337	315
Jacksonville	353	369	311	295	297	293
North Island	400	367	355	298	308	306
Norfolk	441	834	657	530	510	503

Workload in thousands of hours

TABLE B-5. GAS TURBINE ENGINE SHOP WORKLOAD BY DEPOT

Depot	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87
Air Force						
Oklahoma City	1,628	1,693	1,641	1,621	1,694	1,716
San Antonio	3,306	3,215	3,059	3,153	3,280	3,309
Army						
Corpus Christi	266	287	306	299	306	336
Anniston/Mainz	10	16	29	44	59	77
Tooele	0	2	0	2	0	2
Navy						
Alameda	584	527	485	474	491	496
Cherry Point	417	401	386	373	352	312
Jacksonville	239	250	232	230	246	239
North Island	389	357	354	350	352	361
Norfolk	316	598	633	498	433	414

Workloads in thousands of direct labor hours.

Air Force data for FY 82-84 provided by AFLC/MAX. Data for FY 85-87 projected proportional to engine program workload.

Navy data for FY 83-87 provided by NALC 203. FY 82 estimated from induction schedule provided by NALC 223.

Army data supplied by Army Depot System Command.

APPENDIX C

ENGINE PRODUCTION SHOP CAPACITY BY DEPOT

Table C-1 shows the engine production shop capacity for each DoD depot.

TABLE C-1. ENGINE PRODUCTION SHOP CAPACITIES

Depot	Capacity (000s of DLH)	
	Physical	Peacetime
Oklahoma City	2,578	2,088
San Antonio	3,664	2,858
Anniston	49	39
Corpus Christi	359	291
Mainz	49	39
Tooele	68	55
Alameda	781	604
Cherry Point	483	388
Jacksonville	642	473
Norfolk	887	745
North Island	733	585

Air Force depot figures provided by AFLC/MAX.

Army figures provided by Army Depot System Command.

Updated Navy figures provided through JADMAG.

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